Report to the Center of Independent Experts (CIE) on the Report entitled Catching fish, not turtles: Pelagic longlines.

Stephen J. Smith
Department of Fisheries and Oceans
Bedford Institute of Oceanography
Dartmouth, N.S. Canada B2Y 4A2

Executive Summary

This report presents the review of a draft manuscript detailing the analysis and results from a 2002 study initiated by NOAA fisheries and aimed at developing methods to reduce incidental mortality of sea turtles. A number of weaknesses were identified in the statistical analysis of the sea turtle and fish catch data. While circle hooks with mackerel bait appeared to result in large reductions in the odds of catching leatherback and loggerhead turtles, it was not clear under what conditions of temperature and gear soak times these reductions were realized. Increasing temperature resulted in increased catch rates for both species of turtles, while increasing soak time increased the catch rates for loggerheads for this kind of hook and bait. The regression model for the swordfish and tuna catch rates had a number of problems which need to be addressed before the conclusions in the report can be accepted. All of the analyses required assumptions that were not tested. In addition, hook types were evaluated through separate tests of each hook type versus the control hook type. Using this approach instead of testing all hook types simultaneously, could result in the inflation of the Type I error, that is, increasing the actual probability of incorrectly rejecting the null hypothesis higher than the assumed value of 0.10.

Background

In an attempt to reduce the incidental mortality of sea turtles by pelagic longlines which target swordfish, tuna and sharks, the US government has completely banned its fishermen in 2001 from prime fishing grounds in the western North Atlantic Ocean. Lifting of the ban is contingent of the development of fishing methods or gear modifications that reduce or eliminate the incidental mortality of sea turtles. In 2001, NOAA fisheries initiated a three-year study to develop methods and gear that would reduce the mortality of both loggerhead (*Caretta caretta*) and leatherback sea turtles (*Dermochelys coriacea*).

A draft manuscript has been prepared, entitled, '*Catching fish, not turtles: Pelagic longlines'*, by John W. Watson, Sheryan P. Epperly, Arvind K. Shah, and Daniel G. Foster, which details the results of a study in 2002 on reducing turtle bycatch. There is an urgent need for independent peer review of the manuscript in order to meet hard deadlines for rule making and to expedite transfer of the research results to other

countries. Following is an in-depth review of the manuscript focusing on the quality of the research, data analysis, statistical procedures and conclusions.

Review

Two documents were provided for this review. I will refer to pages, tables and figures in the first report (Watson et al. 2004a) with the letter R and likewise, from the printout of the supporting online material from Watson et al. (2004b) with the letter S.

Turtle catch rate

There is a statement in the middle paragraph on page R6 that "No loggerheads had been tagged previously." This sentence conveys no information given that tagging was not mentioned before or after this statement in this document.

Experimental treatments using circle hooks and squid bait were paired with the J hook/squid control on each of sets A and B. Sets denoted as type C include two experimental treatments only, circle hooks and J hooks with mackerel bait. These two experimental treatments are compared against J hook/squid controls even though they do not appear in the same set. These kinds of comparisons of experimental treatments with controls must assume that the probability of catching a turtle on any one hook is independent of bait on neighbouring hooks. There is no discussion about the validity of this assumption.

The authors state that they used a generalized linear model for evaluating the factors that could affect catches of turtles. Specifically, they used a logistic regression model which evaluates the log of the odds ratio of catching a turtle as a linear function of a set of covariates. That is,

$$1) \qquad \log\left(\frac{\pi}{1-\pi}\right) = (\text{Hook type}) + (\text{SST}) + (\text{Soak time}),$$

where, π is the probability of catching a turtle on any one hook. However, the results in the text are all expressed in odds ratios, so that the factors now have a multiplicative effect, i.e.,

$$2) \qquad \left(\frac{\pi}{1-\pi}\right) = \exp(\text{Hook type}) \times \exp(\text{SST}) \times \exp(\text{Soak time}).$$

Generally, if one was to test for differences between hook types, then one logistic model would be fit to all of the data with hook types as a five level factor. Contrasts in the design matrix would be set up so that four of the treatments are compared against the control of J hook with squid bait. This does not appear to have been done here. Instead it

looks like a logistic model was fit to each combination of an experimental treatment and the control. This multiple testing approach may inflate the overall type I error.

In Tables S1 and S2, the results of the analyses for loggerhead and leatherback, respectively, are presented in terms of odds ratios. These results are very confusing as it is not clear that the odds ratio presented for hook type, for example, are actually a fitted value of some sort for constant values of the other covariates or actually estimates of the factor exp(Hook type). The interpretation in the second paragraph of page R7 for the mackerel bait measurements seems to indicate that it is the latter. That is, a point estimate of 0.096 (rounded to 0.10 in the text) in Table S1 for treatment C_2M, does indicate that the Circle Hook with mackerel bait reduces the odds of catching a turtle relative to a J hook with squid bait. In fact, the text presents the inverse of this statement, that is, the odds of catching a turtle on the control hook and bait was 10 times that of the experimental hook and bait.

I will assume that the estimates in Tables S1 and S2 are the multiplicative factors in equation 2 as they do not make sense as they are currently labelled as odds ratio. However, the interpretations of the effects of sea surface temperature (SST) and soak times in paragraph 3 and 4 on page R7 (and top of page R9) are still problematic. The text states that "The loggerhead turtle catch rate increased by a multiplicative factor of 25% to 35% with one degree C increase in sea surface temperature (odds ratio varied from 1.25 to 1.35 depending upon treatment comparisons." It makes more sense to state that the "odds ratios" of catching turtles increased by a factor ranging from 1.25 to 1.35 for a change of one degree in temperature — for fixed values of all other factors. Therefore, 1.25 and 1.35 correspond to $\exp(\beta_T)$ where, β_T is the slope of the temperature relationship. The factors for the increase of 5 degrees C given in the text can be reproduced here by noting that $\exp(\ln(1.25)\times 5)=3.05$ and $\exp(\log(1.35)\times 5)=4.48$.

On page S8, the text states that all analyses utilized the original units of measurements, specifically temperature in degrees Fahrenheit. In the captions for tables S1 to S4, it is stated that results for temperatures are also reported in degrees Fahrenheit. However, all of the discussion on pages R7, R9 and R12 use results from these tables but apply them to degrees C. Indeed, on page R7 (and in Figure S5), the range of temperatures in the study area was given as 11 to 24° C. If the parameter estimates correspond to fitting temperatures in degrees Fahrenheit then they need to be adjusted for application to degrees Centigrade. If the authors want to express results in degrees C, then the model should be fit to temperature as degrees C.

Given that soak time is measured in minutes, the magnitude in change for this parameter can be quite serious for loggerhead turtles and this fact does not appear in the discussion of this factor. For example, while it would take an 8.7 degree change in temperature to negate the advantages of using treatment C_2S, it would only require a four hour increase in total soak time for a constant temperature. It would only require an increase of three hours if the temperature increased by 2 degrees.

In all, it is difficult to assess the impact of circle hook/bait treatments on reducing the odds of catching a turtle relative to the effects of temperature and/or soak time. We need more information concerning how temperature and soak time were fitted into the model. For example if each of these covariates had been centered by their means, then the point estimate for hook type by itself would indicate the expected reduction in the odds ratio for the average temperature and average soak time. The impact of having temperatures higher than average, could be evaluated and then recommendations such as fishing in cooler waters (page R13) would have more meaning. The impact of having soak times longer or shorter than average on the odds ratio would be more straightforward and also lead to more meaningful advice.

Daylight soak time and total soak time are probably highly correlated/aliased as suggested by the authors. The effect of this correlation could be ascertained by comparing parameter estimates when Daylight soak time is sequentially added to the model before or after Total soak time is. We don't know what order the factors were added to the model unless the order corresponds to that given in the tables.

Implicit in all of this is that temperature (and soak time) affects experiment hook/bait treatments control/bait treatments equally, that is, the slopes for temperature and soak time were the same for experimental and control treatments. This would seem to be a very important assumption, although there was nothing in the report about it being tested. In addition, the analysis seems to be based on the assumption that the effects of soak time are independent of temperature. This assumption should be tested with an interaction term.

An analysis of deviance using a χ^2 would have been more informative than presenting Wald confidence intervals. From these results we could evaluate the possibility of overdispersion by evaluating the ratio of residual deviance to degrees of freedom. Diagnostics such as residuals plotted against properly scaled fitted values (2×arcsin of the square root of the fitted values in this case, see McCullagh and Nelder 1989) or against each the explanatory variables would help evaluate whether linear terms for temperature and soak time were appropriate.

Comments on Page S8 about using 1-odds ratio to provide an estimate of the reduction rate do not make any sense. Algebraically, you would get

$$\begin{aligned} 1-\frac{\pi}{1-\pi} &= \frac{1-\pi}{1-\pi}-\frac{\pi}{1-\pi} \\ &= \frac{1-\pi-\pi}{1-\pi} \\ &= \frac{1-2\pi}{1-\pi}, \end{aligned}$$

which does not appear to be a reduction measure of any kind. Further, if the "odds ratios" as presented in Tables S1 and S2, are really multiplicative factor estimates as

interpreted above, then any estimate less than 1.0 will result in a reduction in the odds ratio and any estimate greater than 1.0 will result in an increase.

On page R6, the text states that 100 loggerheads were caught during the course of the experiment. On page R8 we are told that 34 turtles were hooked in the mouth and 59 in the oesophagus. At this point, the text should reference Table R1 because it is not clear in the text if these figures are for circle hooks (mentioned in the topic sentence for this paragraph) or for both hooks. However, the table does not break down the numbers by hook type. Further on in the paragraph, we are told that 27.3% (n=3) of the loggerheads caught on circle hooks swallowed the hooks, indicating that only 11 of the total number of loggerheads caught were actually caught on circle hooks. Of those animals caught on J hooks, 66.7% (n=56) swallowed them. We seem to be missing some animals here as 56/(100-11) equals 62.9% not 66.7%. These are probably the 5 animals in the table listed as not hooked or not known if hooked. Were these animals entangled? These results would be much easier to understand if the actual breakdown by at least hook type was given in a table.

There were a total of 158 leatherback turtles caught in the study. It is more difficult to determine from the text on pages R9 and R10 how many were caught in the various different ways. The text states that 113 were hooked externally but it does not state what the breakdown was by gear. In Table R1, a total of 122 leatherbacks were listed as being hooked externally. Why is there a discrepancy between the text and table? As above, it would be helpful to have the numbers broken down by at least hook type.

Catches of tuna and swordfish

The variable to be modelled in this part of the analyses was defined to be catch weight per hook (page S8). There were 489 longline sets with the number of hooks ranging from 210 to 1173. Assuming an equal number of set types (A, B or C), that means there were 163 sets for each treatment type. For any one set, the observed random variable was the single ratio of the total weight caught for a particular hook/bait type divided by the number of hooks — I am assuming that includes both hooks with and without fish on them. Ratios rarely follow normal distributions such as assumed for the regression analysis used here and no diagnostics are presented to evaluate this assumption. An alternative approach would be to fit the regression to the total weight and use the number of hooks as a covariate.

The text states that the analysis used weight in pounds but Figure R2 presents weight in kilograms and the text on page R6 uses metric tonnes. Do the coefficients correspond to fitting the model to weight in pounds or kilograms per hook?

On page R11, percentage increase or decrease of swordfish catch is presented for the various hook/bait types. It is not obvious how to line up these increases/decreases with the parameter estimates in Tables S3 and S4. For the results on C_2M, does the estimate for hook type indicate that the catch rate for swordfish was 0.589 lb/hook higher for the circle hook and does this correspond to the 30 percent in the text?

Many of the criticisms raised above for the logistic model apply here. Given that soak time is measured in minutes, this factor could have a big effect on the catch of tuna. It would be more informative to fit the model with soak time (and temperature) centered by their respective means, so that we can evaluate the effects of the hook/bait types for the average conditions (assuming temperature and soak time have independent effects).

Conclusions/Recommendations

It is difficult to evaluate the effects of hook/bait type on reducing the odds of catching sea turtles on pelagic longlines independently of the other factors of temperature and soak time measured in the experiment. The results from the logistic regression are very difficult to interpret as presented. It is not obvious what the correspondence is between the reductions due to hook/bait type and the typical temperatures and soak times that may occur in actual fishing practice. I recommend that the authors address all of the comments presented above on their analysis either by clarifying the text and/or redoing the analysis. A number of modifications to the analyses have been suggested. For example, centering the temperature and soak time by their respective means would provide more interpretable estimates of the effect of hook type under typical conditions. A number of assumptions have to be evaluated, such as the assumption that soak time and temperature are independent. In addition, hook types were evaluated through separate tests of each hook type versus the control hook type. Using this approach instead of testing all hook types simultaneously, could result in the inflation of the Type I error, that is, increasing the actual probability of falsely rejecting the null hypothesis higher than the assumed value of 0.10.

Catch rates for swordfish and tuna are ratio estimates and may result in the assumption of normal distribution of errors being violated for the regression analysis. The results of these analyses need to be clarified or the analyses need to be redone to answer the questions raised above.

Model diagnostics for all of the analyses conducted here are conspicuous by their absence. If nothing else, evaluation of residual plots should be included.

Appendix I: Bibliography

McCullagh, P. and J. A. Nelder. 1989. Generalized linear models. Chapman and Hall. London. Second edition. 511 pp.

Watson, J. W., S. P. Epperly, A. K. Shah, and D. G. Foster. 2004a. Catching fish, not turtles: Pelagic longlines. 15 pp. + 1 table & 4 figures.

Watson, J. W., S. P. Epperly, A. K. Shah, and D. G. Foster. 2004b. Supporting online material for Catching fish, not turtles: Pelagic longlines. 10 pp. + 4 tables & 7 figures.

Appendix II: Statement of Work.

Statement of Work

Consulting Agreement between the University of Miami and Stephen Smith

January 29, 2004

General

Incidental capture of sea turtles in fisheries is one of the most significant threats to their survival and recovery. Possible management measures addressing the incidental take and mortalities of endangered and threatened sea turtle species by U.S. pelagic longline fisheries are derived from research to design, develop, and evaluate gear and/or tactical measures capable of significantly reducing the interaction between sea turtles and longline fishing gear. In 2001, NOAA Fisheries initiated a three-year cooperative research program in the western Atlantic Ocean to develop and evaluate fishing technology and tactics to reduce the incidental capture and mortality of sea turtles by pelagic longline gears. This research program was successful in developing fishing techniques that significantly reduce the interaction of both loggerhead (*Caretta caretta*) and leatherback sea turtles (*Dermochelys coriacea*) with pelagic longline gear and tools and techniques to remove gear from the turtles that do interact with the gear. NOAA Fisheries is proposing rule making to require the use of this gear by U.S. pelagic fishers in the southeastern United States.

Pelagic longline fleets of other nations comprise over 90% of the longline fishing effort in the Atlantic. A major emphasis of the U.S. gear development research effort will be to transfer successful technology and encourage the use of practical measures to reduce sea turtle interactions by foreign fleets.

In order to provide information for rule making and technology transfer to other nations, a draft manuscript has been prepared, titled, '*Catching fish, not turtles: Pelagic longlines'*, by John W. Watson, Sheryan P. Epperly, Arvind K. Shah, and Daniel G. Foster. There is an urgent need for independent peer review of the manuscript in order to meet hard deadlines for rule making and to expedite transfer of the research results to other countries.

Specific

The consultant shall conduct an in-depth review of the manuscript and provide a written professional evaluation of the quality of the research, data analysis, statistical procedures, and conclusions contained in the manuscript.

The consultant shall review the experimental design and data analysis and provide written comments on whether the data and data analysis support the conclusion that the treatments tested significantly reduce the interaction of sea turtles with pelagic longline gear under the conditions tested. Specifically, the consultant shall provide written evaluation of the appropriateness of the experimental design, the appropriateness of the statistical procedures used in the analyses of the data and whether the data and analyses support the conclusions. The consultant will also provide comments on additional research needed if appropriate.

The consultant's tasks, which will take a maximum of three days, shall consist of:

1. Conducting an in-depth review of the manuscript and providing a written professional evaluation of the quality of the research, data analysis, statistical procedures, and conclusions contained in the manuscript;

2. Completing a written report (See Annex I) no later than February 13, 2004 and submitting it to "University of Miami Independent System for Peer Review" and sent to Dr. David Sampson, via email to david.sampson@oregonstate.edu and to Mr. Manoj Shivlani, via email to mshivlani@rsmas.miami.edu.